Virtual National Laboratory for Heavy Ion Fusion

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HIF News

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Plasma Source Development for Charge Neutralization Experiments

Minimizing the size of the focal spot on the target will help to minimize the cost-of-electricity from an HIF power plant. However, space charge will expand the focal spot of a typical heavy-ion beam, to beyond the emittance limited spot size, unless the beam is partially charge neutralized. One promising approach achieves charge neutralization by propagating the ion beams through a large-volume plasma. PPPL is developing electron cyclotron resonant (ECR) and helicon plasma sources to be used in the near-term experiments: NTX and HCX. This article describes initial results with an ECR source.

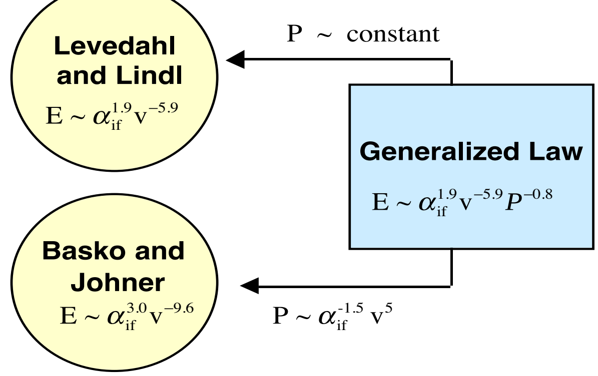
The photograph shows an argon plasma created in the 4" diameter source at a pressure of 4 milliTorr. It is supported with a few hundred watts of 13 MHz radio frequency (RF) power and 20 gauss of magnetic field. The plasma extends along the 12" length of the chamber. The RF waves are coupled through a quartz window at the back of the device with an enclosed spiral antenna. A Langmuir probe is connected to the right of the chamber. With this, plasma densities have been measured from 10^8 to 10^{11} cm^{-3}, and the electron temperature determined to be 10 eV.

The next activities include replacing the mechanical pump to allow operation below 1 milliTorr. At that point the operating gas will be hydrogen. Wave coupling will switch to a side wall launch to improve integration with beam drift tubes. — *P. C. Efthimion and R. C. Davidson*

A generalized scaling law for the ignition of inertial confinement fusion capsules

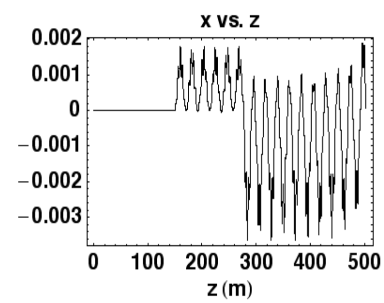
How much energy is needed to ignite an inertial confinement fusion capsule? This is of considerable interest in the optimization of an inertial fusion driver, since the driver energy is a monotonically increasing function of the capsule ignition energy. The minimum energy for ignition has been expressed as a scaling law in terms of the capsule implosion velocity and the capsule fuel adiabat. Recent work on computational scaling laws found, unexpectedly, that the capsule drive pressure strongly affected the ignition energy. To study this effect we created a database of barely ignited capsules in which the drive pressure, implosion velocity, and the fuel adiabat are varied independently. The drive pressure was found to affect the increase in the fuel adiabat that occurs during capsule stagnation. The stagnation fuel adiabat, in turn, affects the ignition energy. This is an effect that had not previously been appreciated. While this work relied on detailed numerical simulations, self-similar ICF-like implosions are also found to exhibit this effect.

A generalized scaling law for the ignition energy that depends on the implosion velocity, fuel adiabat, and drive pressure was found, and recently published in Physics of Plasmas. This scaling law agrees with the previous computational work in the appropriate limits (see figure). – *Mark Herrmann, Max Tabak, John Lindl*

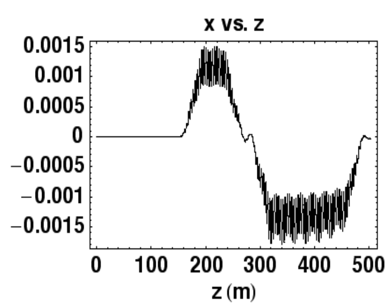


Dispersion of the Beam's Centroid During Final Compression

Two sided heating of a target by beams from a single accelerator requires that the ion beams be bent through angles totaling ~180^o, while being drift-compressed from ~200 ns to ~8 ns. Drift-compression is done over a distance of ~300 m by means of a velocity tilt on the beam. This introduces the issue of dispersion in non-achromatic bends. Dispersion, which could reach several cm, can be limited to a few mm by using a short, constant lattice period through the entire system, and by allowing the beam radius to increase naturally as the square root of the current.



A more subtle issue, addressed in a recent PAC paper, is the degree to which the centroid can be matched and returned to the design orbit at the end of the bend system, e.g. effective achromaticity. This is complicated by the varying current, bend strengths, tilt, and (possibly) lattice parameters. We used a simple set of model equations to track the centroid through a compression section. An abrupt turn-on of a bend set produces, as expected, an unmatched oscillation of the centroid and a significantly misdirected orbit entering final focus (upper figure). A better strategy is to adiabatically (gradually) turn on (and off) the bend strengths over 1-2 betatron periods. The centroid of an off-momentum beam slice then smoothly adjusts to a matched off-axis orbit and returns very closely to the design orbit at the system end with less than 0.1 mm displacement (lower figure). A general mathematical principle, giving conditions for the validity of adiabaticity in a system of discrete elements, would be of great value. – *Edward Lee and John Barnard*



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